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New Parameters for Improving "DYFI?": Factors Influencing User Participation in Citizen Seismology

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Abstract

Through qualitative and quantitative analysis of USGS's Did You Feel It (DYFI) "additional comments" (textual reports), the study explored user engagement with the DYFI system. While methods currently exist to quantitatively evaluate the geopolitical and socioeconomic factors that may drive response rate across particular regions, DYFI's textual reports have only rarely been examined to generate a more robust picture of the socio-cultural factors shaping user engagement. Building off the idea that observer comments constitute "personal narratives" - forms of social practice where individuals position themselves in a dialogue with science and institutions (Coen 2012; Valencius 2012) – the study's findings offer a window onto users' attitudes, conditions and expectations when interacting with DYFI. Data was collected from events in north central, central, and east-central Oklahoma between 2010-2016. This period experienced a drastic spike in seismicity in this region, which scientists have linked to energy extraction-related activities (Ellsworth 2013; Keranen and Weingarten 2018). As areas with historically low exposure to seismic hazard become salient for "induced" or intraplate seismicity, DYFI's "user comments" are useful for measuring and contextualizing the forces that shape science crowdsourcing in different locations. The study employed a qualitative data analysis software to generate data-driven categories that would capture users' profile, behaviors, and motivations, making the textual data actionable as data points. The findings suggest the influence of social roles, geosocial context, perceptions of social crisis, cultural attitudes, user fatigue, and social media in user engagement with DYFI as well as the trajectory of specific rhetorical appeals and themes as they decreased or increased over time. Most users, however, built off of the language and prompt of the DYFI questionnaire to structure their "comments," and such a finding invites inquiry into what types of information different questions/format would elicit from users. Users desire to interact in a two-way channel with the scientists behind DYFI is also documented. These and other implications are outlined. The study sets a groundwork for future studies of user engagement in government-sponsored crowdsourcing, particularly as the present method and findings could be combined with other forms of data such as socioeconomic status and demographics for which metrics have been tested. The process, challenges, and limitations of large-scale, mixed-methods analysis of qualitative data are also discussed, as these can inform future studies. Ultimately, the study brings to the fore enduring challenges in integrating public observers into seismic data collection – challenges where at stake is not necessarily whether public participation is useful, but further, conflicting visions of what role "lay" earthquake observers ought to play in the governance of seismic risk.

Report

Overview:

The project examined user engagement in USGS's "Did You Feel It?" (DYFI) online felt report system through the analysis of textual, first-person accounts (qualitative data) that users generate when completing the online DYFI questionnaire. The data set corresponds to earthquakes in Oklahoma between the years 2010-2016—the period that marked the sudden spike in seismicity in this newly salient "intraplate region." The PI employed a qualitative data analysis software to probe the social profile, motivations, and expectations of responders over time and to generate meaningful data-driven findings. Data analysis comprised organizing, sampling, manual and automatic iterative "coding" (labeling phenomena based on a "grounded theory approach" that allows for categories to emerge from data), and analysis of code frequencies and code interactions. Coded segments were iteratively reviewed for accuracy, then visualized quantitively to identity patterns, trends, and deviations, and lastly, linked across lists to test and discover new relationships and categories. As a result, 36,966 anonymized individual responses were analyzed. Of these, 69,896 user comments were sub-coded and coded. The findings suggest the influence of social roles, geosocial context, perceptions of social crisis, cultural attitudes, user fatigue, and social media in user engagement with DYFI as well as the trajectory of specific rhetorical appeals and themes as they decreased or increased over time. The process, challenges, and limitations of large-scale, mixed-methods analysis of qualitative data are discussed as these can inform future studies.

Methodology:

***Data Collection*:** From a larger data set consisting of >Mag. 2.0 events' DYFI anonymized individual responses for the Oklahoma region - coordinates [33.886, 37] Latitude [-99.998, -94.449] – from the years 2010-2016, a final data sample of 19 events was selected for analysis. The sample selection was based on the following criteria: first, the location of the epicenter in north central, central, and east-central Oklahoma, comprising the cities/towns of Oklahoma City, Edmond, Stillwater, Cushing, Prague, Edmond, Spencer, and Pawnee. During the 2010-2016 time-period, this region was considered the "area of interest" in the sustained spike in seismicity. Next, because of available statistics for California (Celsi et. al 2005), which point that approximately 25% of responders provide a textual comment when submitting a DYFI felt report, entries with the maximum number of responders were selected. Third, at least two events per year spread roughly between the first and second half of the calendar year Jan-June and July-Dec were selected. For years with sustained seismic activity and high response rate, such as 2015, four events were taken as representative. The year 2010 marked the period immediately preceding heightened social debates over the cause of the seismicity and also is represented by four events to solidify a baseline given the comparatively low response rate. Conversely, for the year 2011 the second biggest magnitude earthquake in Oklahoma history is taken as representative because the number of user entries exceeded the maximum threshold for analysis. And for the year 2012 a single event with the maximum amount of responses functions as a variable given the otherwise stable distribution of responses throughout the year. A total to of 36, 966 anonymized individual responses were sampled for automatic and manual analysis (Figure 1). With the sampling finalized, the individual responses per event were converted into word

format and imported into the MAXQDA software as individual documents. Once the data was uploaded to the software, the PI followed a three-stage process: 1) preliminary data review, 2) exploratory coding and analysis, 3) final coding and analysis.

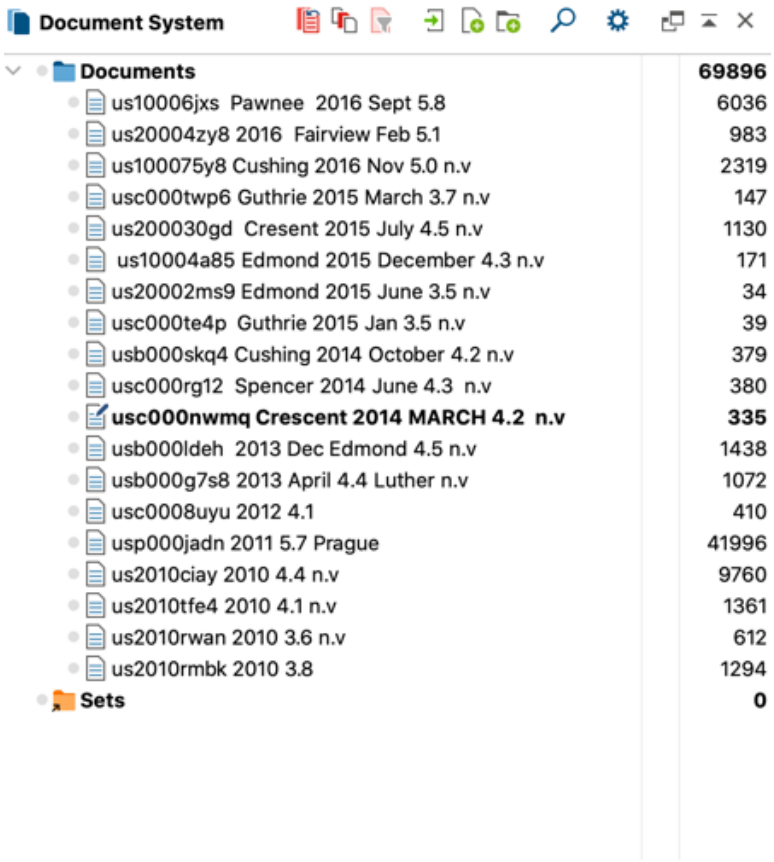

Figure 1, Data-set

Data Analysis:

For the *preliminary data review stage*, the PI aimed to develop familiarity with the content of the data to refine the analysis parameters. The PI tested the extent through which the data could answer general questions about users' profile and behavior, including demographics, reporting context, epistemology - or the nature and basis of knowledge claims - and motivations. In other words, could the data-set answer general questions about "Who am I? Where am I? How do I know what I know? And why am I reporting?" To do this, exploratory lexical searches were conducted where the software "scans" documents to extract particular keywords and interpret regular written speech expression. "Keyword clusters," or a set of terms taken as representative of particular category of phenomena, are used (Figure 2 as example). For example, would users' invocations of people whether of "spouses, children, or co-workers" answer the question "Who am I?" or shed light on social roles, obligations, or on reporting context? Or can a disparate cluster of keywords such as "damage, anxiety, fear, stress, exciting," yield any "hits" (the result of the lexical queries are "hits" that can be reviewed, managed, and coded with different identifier options, see Figure 3). Alternatively, would a keyword cluster with terms associated with science and governments, and with the oil and gas industry, yield any significant hits that

could point to users' concerns and motivations? This process was both automatic - the software extracts data – and manual to iteratively review what was being captured and not captured by these searches. This process was exploratory: from broad to specific, and then back to broad if the data did not respond to the query. Initially, the categories encapsulated on the keyword clusters were either too broad or too narrow as the PI was trying to gain a sense of the scope and content-range of the data. The purpose was to test expectations about the content of the data and to probe the tone and language of users against the PI's searches. Thus, the process built on both expectations/proposed parameters and real-time engagement with the data based on a grounded theory approach where data drives the analysis to identify self-defining parameters and testing the pertinence of imposed categories by switching gears to adopt new ones and noting the ones that lack representation within the data. For the PI, this stage involved teaching herself to know the data and its complexities while tallying relevant results as they emerged. Some of the implications of this stage became readily evident. Social roles could be more feasibly analyzed than socioeconomic status, for instance. Mentions of socio-politically motivated reports did not yield a high rate of response, whereas interrogative commands had a higher response rate, which suggested that users were posing questions, ostensibly to the scientists behind DYFI. The need to inquire further into language use was eliminated as only English was used and other languages were not represented in the data.

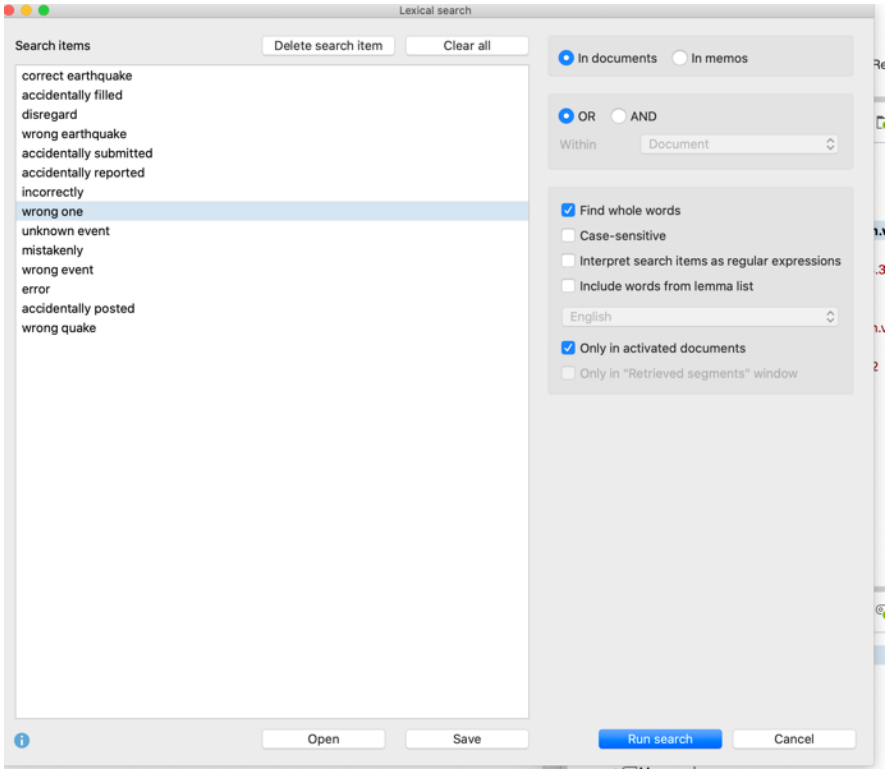

Figure 2, Example of lexical search of keyword clusters

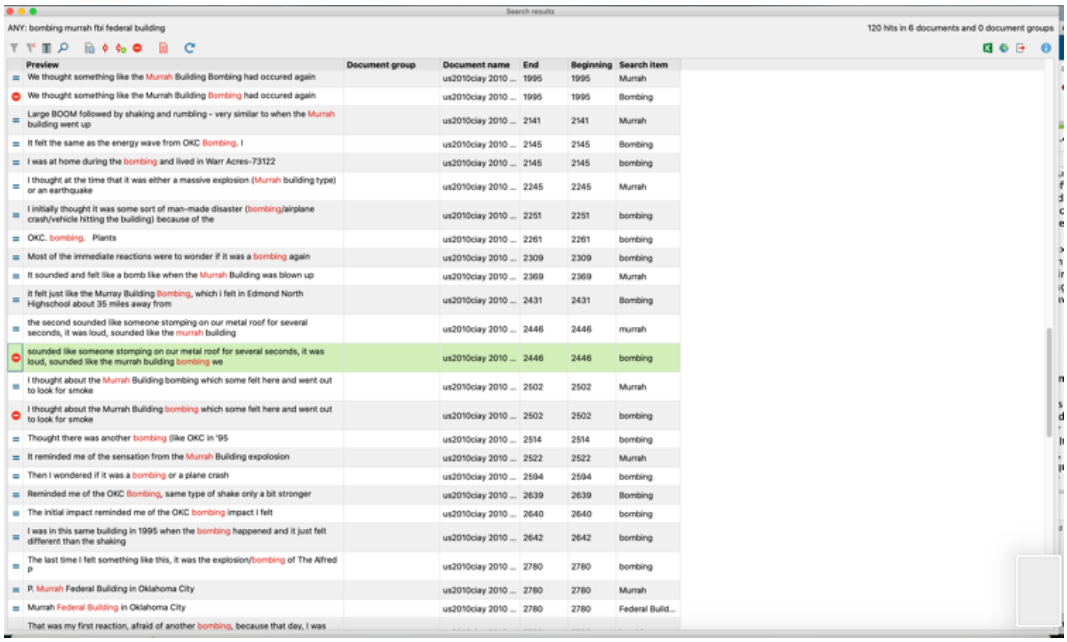

Figure 3, Example of lexical search results lists

With emerging familiarity with data about the range of what could be feasibly analyzed, during the second stage the PI pursued more specific coding queries. For the *exploratory sub-coding and coding stage*, several codes were imposed on the data and iteratively reviewed manually to check what we were missing or what did not reflect the data. The category of "catch all" *sub-codes* was identified when certain, usually small keyword-clusters reflected in an over 80% of user responses, such as "felt, feel, feeling." These coded lists were put aside for future complex code queries where code interactions could potentially clarify the context of the users' mentions of the catch-all code. For example, what forms of knowledge structure user statements of "what I felt?"—or how is "feeling" the earthquake understood, expressed, and evidenced? Similarly, the code "report, reported, reporting" is another catch-all "sub-code" as it may refer to the act of DYFI reporting or to the more ordinary use of the term as when the news or the police "report" something. Thus, without any other kind of parameter about the context of users' explicit assertions of the act of reporting, its high prevalence complicates both manual and automatic analysis.

In addition to identifying these catch-all sub-codes for future complex queries, three focused lexical inquiries were explored to polish the codes list. These were appeals to 1) debates over the cause of the earthquake, 2) to the relationship between the users' social worlds and DYFI reporting, and 3) to a dialogue with USGS-DYFI. For instance, the cluster: "oil drilling fracking, petroleum, oil and gas, extraction, pump jack, refinery, petrochemical, tanks storage, etc.," and the cluster of "manmade, induced, frack-quake, natural" for #1. A longer list of social roles/identifiers such as "friend, neighbors, she, he, husband, wife," etc. (along with plural and singular spellings when required to avoid missing data) to refine a potential query for #2. And, "USGS, DYFI, did you feel it, science, scientist, scientists, federal scientists, etc.," along with a separate list including "please, call me, let me know, back to me, contact me," etc. for #3. As done for stage 1, search results lists were manually revised but not altered as at this stage it was more effective to just re-do the queries. Thus, this stage was also iterative. Manually examining the events documents themselves (not the search results hits lists), however, was also necessary

to identify what if anything was not been captured by the searches and to discover potential categories for prospective coding. For instance, a category of "damage" that includes keywords such as "cracks, foundation, damage, brick, structural" as a motivation for DYFI reporting emerged as a critical category due to manual reviews. Lastly, during this stage, the researcher identified issues in the ways the software was extracting data, as slightly different document formatting would make the software "skip" some user entries. To avoid discrepancies so that the software features would work evenly across all data, all documents were individually reformatted and reuploaded. Overall, this stage was critical for testing, updating (whether expanding the code categories or narrowing them), and confirming the codes list as it took shape.

For the *final sub-coding and coding stage*, the PI built on the data points gathered during the prior two stages to ask the data about: ways of knowing and/or "feeling," (auditory, visual, bodily-based, place-based, and the respective keyword-clusters that represent each (e.g., auditory = sound, sounded, sounding, heard, hearing, hear, loud, cracking, rattling, rattled, rattle, loud, noise, noises, etc.). The influence of the following factors on DYFI participation was also probed: assertions of not feeling the quake (e.g., "did not feel, didn't feel, didn't realize); the role of government institutions/dynamics; the 1995 Oklahoma federal Murrah building bombing; the role of pets, animals, and of objects from the users' social and natural environment; the role of being a parental figure; appeals to the USGS (e.g. "website, your website, DYFI, did you feel it, federal scientists, government scientists Did You Feel It); the role of perceptions of social controversy over the phenomena's cause (Extraction-Quake Controversy; appeals to the cause of the earthquake (natural vs. induced/man-made; an independent "causation" inquiry/statement merged as a "catch-all" sub-code, see above); perceptions of uncertainty; the role of perceptions of being prepared vs. unprepared and of expressing disconcertedness/fear versus excitement; the role of perceptions of "damage;" the role of social media and other media forms, and of smartphones; perceptions of emergency; and the role of religious beliefs. The prevalence of assertions of first-earthquake experience, of responses that elucidate the individual/collective actions that emerged in the aftermath of the seismic/event (i.e., What I was/am doing and will do), and of assertions of reporting errors/ incorrect reporting, were probed. "Statement of report," or direct invocations of the act of reporting, as well responses structured around "my experience" were confirmed as "catch-all" subcodes (see above). Lastly, although maintained as variables, the coded inquiries about the USGS as an institution [e.g., science, USGS, website, scientists, etc.,] and about social debates over the cause of the phenomena generated a relatively low response rate. The searches results lists were manually examined for accuracy as feasible—all for hits lists under 300 items and the first 50 items of larger search hits lists—to eliminate false positives due to duplicates, misspellings, or the misidentification of language expressions. After the coding finalized results were visualized over time. The relationships suggested above between certain user contexts, circumstances, or worldviews and forms of action were explored through the "complex code query" function where two or more codes can be automatically probed for intersections (Figure 4). This process produced 69,896 sub-coded and coded segments (see Figure 5).

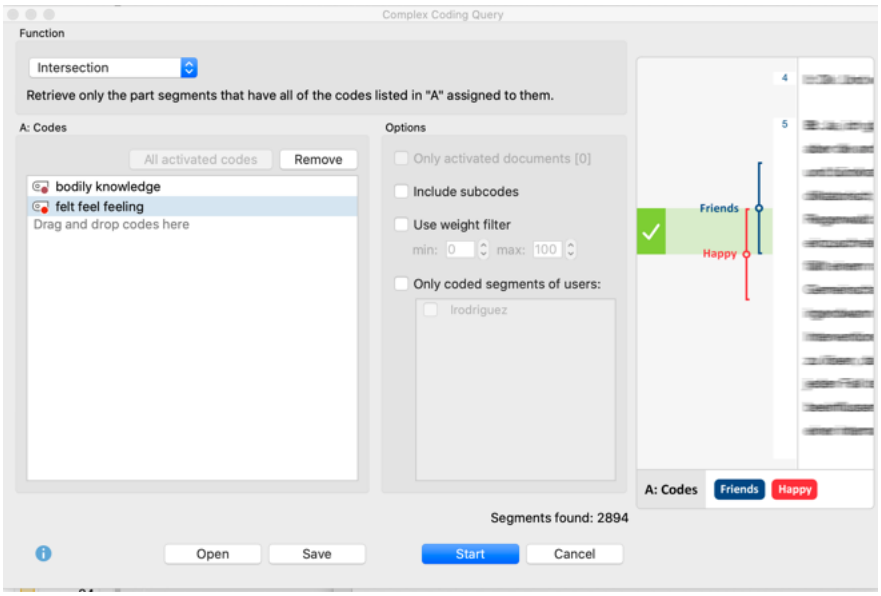

Figure 4, complex coding query example

Code Frequencies

Unit: Segments with code

	Frequency	Percentage
felt feel feeling	15,707	22.5
Sound and knowing	9,311	13.3
Myself and People aroun...	5,908	8.5
bodily knowledge	5,066	7.2
What I/we heard, and ...	4,514	6.5
People around me and ...	3,878	5.5
Damage	3,810	5.5
See / saw /seeing / visibl...	2,378	3.4
Pets / Animals	2,304	3.3
What I was/am doing an...	1,905	2.7
My first Earthquake	1,812	2.6
Fear/Disconcerted	1,522	2.2
fell off moved askew	1,521	2.2
Parental figure	1,468	2.1
Seeing and Feeling	1,335	1.9
California CA Alaska San...	1,236	1.8
Did not feel	795	1.1
fell off askew shifted to ...	760	1.1
Report/Reporting/...	702	1.0
My experience	649	0.9
Excitement	586	0.8
Uncertainty Statement	546	0.8
Social media	442	0.6
Extraction-Quakes ...	282	0.4
Orientation- lateral east-...	244	0.3
dialogue with DYFI	223	0.3
USGS	152	0.2
Parental figure and my fi...	104	0.1
911 / Emergency	84	0.1
Religion	80	0.1
1995 Murrah bombing	79	0.1
TV news local news local...	62	0.1
Reporting Error	56	0.1
Police	52	0.1
Social Media and ...	51	0.1
Did not feel and Report ...	40	0.1
My first EQ and Reporting	37	0.1
Parental figure and ...	35	0.1
911 / Emergency	84	0.1
Religion	80	0.1
1995 Murrah bombing	79	0.1
TV news local news local...	62	0.1
Reporting Error	56	0.1
Police	52	0.1
Social Media and ...	51	0.1
Did not feel and Report ...	40	0.1
My first EQ and Reporting	37	0.1
Parental figure and ...	35	0.1
Causation inquiry/...	32	0.0
Government	25	0.0
Preparedness Statement	24	0.0
stress stressed stressing	17	0.0
first EQ and dialogue wit...	14	0.0
Natural / tectonic	12	0.0
Parental figure and ...	11	0.0
iphone / smartphone	9	0.0
Induced event statement	9	0.0
Controversy and Reporting	7	0.0
TOTAL	69,896	100.0

Figure 5, Final tally of coded segments

Findings and Implications:

The ratio of response rate and user provided textual accounts was not steady throughout the period under study. The #2ms9 M. 3.5 event in 2015 had 80 user entries of which 26, or roughly 32%, provided a "comment." This percentage exceeded the expected ratio of 25% (Celsi et. al 2005). However, this average was even higher in the years preceding 2015, which had the highest frequency of earthquakes in the region under study, and on 2016, which saw the biggest seismic event in Oklahoma's recorded history. For instance, the 2010 #us2010rwan M. 3.6 event had 793 user entries and 330 user comments, which is more than 41%. By 2016, however, this user response-comments ratio decreased considerably. For the #4zy8 Fairview 2016 event, out of 4,049 user entries 676 left comments, which is less than 17% of entries. DYFI's "user fatigue" in the context of Oklahoma's spike in seismicity during the period under study had also been noted ethnographically by the present researcher.

The study documents how DYFI users' ground, justify, and evidence their knowledge claims. Forms of knowing based on what observers heard, saw, and felt physically dominate the content of user comments. Sound/hearing stands outs out he most prevalent source of knowing and evidencing knowledge. This remains stable throughout the time under study. Similarly, the high incidence of first-person accounts in which users narrate and ground their experience either 1) through someone else's experience, 2) through their interactions with someone else/or in relation to someone else, and 3) in relation to social roles, is noteworthy. These data points invite questions into particular socio-cultural construction of "feeling the earthquake." Or, what does it mean to "feel" seismic phenomena in the context of sudden, drastic changes in a place's seismicity? In a similar vein, this data point invites inquiries into the ways DYFI participants' fashion themselves as "credible" observers around certain rhetorical strategies.

Of the categories with larger prevalence: fear/disconcertedness decreased gradually over time, whereas all other categories (codes) appear to remain stable throughout the time-period. The study identified a high-incidence of first-time DYFI users in tandem with users' direct, self-conscious statements of the subjective nature of their own reports. Through the present method and tools, the social roles of responders could be more feasibly identified than socioeconomic status, race, or gender identity which are more challenging to extract as data points from the qualitive data sets alone. Two high-prevalence codes shed light on this possibility a) parental figure, and b) myself and people around me, both which attempted to capture the relationship between a particular social role and DYFI participation, as well as the ways in which users structure their experiences through interpersonal relationships.

Assertiveness surrounding socio-politically motivated reports (related to the cause of the earthquake or the social debates surrounding the seismicity) did not yield a high rate of responses, whereas interrogative words did, which suggested that users were ostensibly posing question to the scientists behind DYFI. However, when assessed closely the study only yielded 223 instances of such action (code=Dialogue with USGS). It is noteworthy, that of these, a disproportionally high percentage of users who sought out communication with the DYFI relative to the number of responders per event, occurred in the year 2015. Less statistically significant yet notable are users' direct critiques of the ways the DYFI questionnaire constrained potential answers and open-ended dialogue.

The need to inquire further into language use (English versus other languages) was eliminated as it did not represent the data. The role of existing or potential home damage had a high prevalence. Respondents' appeals to the role of local government institutions and officials

in addressing the seismicity increased gradually between 2010-2016 whereas appeals to religious belief or non-scientific grounds decreased during the same period.

Most responders built off of the language and prompt of the DYFI system to structure their "comments" around "what I felt" (however "feeling" was evidenced or expressed, see above). Such data point invites inquiry into what types of information different questions/format would elicit from users. Overall, the nature of the comments was considerably less "open-ended" than the PI had anticipated.

Study Limitations:

The study explored a method for making DYFI user comments accessible as data points for evaluating and potentially improving the DYFI online felt report system. Because it is based solely on qualitative and quantitative content analysis, beyond 1) the written data provided by users themselves, and 2) the epicenter of the sample selection, the study does not substantively assess the relationship between user comments and geographic location. Such linkage could shed light on spatial and socioeconomic variables (including access to technology, as well as race/identity variables) ostensibly linked to zip-code and locality, for example (see Mak and Schorlemmer 2016; Hough and Martin 2021).

In addition, the analysis tools employed themselves pose challenges for making large volumes of qualitative data automatically accessible in a reliable manner. The tools utilized were prone to misidentifying data and furnishing "hits" (see methods section above) that were false-positives (e.g., duplicates, misspellings, misidentification of language expressions). However, establishing a justifiable margin of error to account for automatically misidentified data in tandem with manual reviews of results as the present study did, could clarify this issue. The analysis system employed has limited options for copying/pasting text which could make the creation of search categories/lexical searches labor intensive. Overall, however, the tool was useful for discovering and defining analytical parameters in large volumes of qualitative data.

Findings are context-specific to the extent that a) the seismic region under study experienced a not previously documented increase in the frequency of seismic events, and b) the increase in seismicity remains associated with sociopolitical disputes over the expansion of some forms of fossil fuel extraction (hydraulic fracturing).

These challenges however sit at the very center of larger questions about the adequateness of making the personal narratives of "earthquake observers" into "extractable texts" versus a more "open-ended" engagement with manageable, localized data sets that harkens back to early citizen-earthquake science "dialogues" (Coen 2012; Valencius 2012). In either case, at stake are institutional priorities and constraints in tandem with the forms of localized, regional, or global knowledges that are considered pertinent at specific historical periods.

Project data: Upon request by the USGS program officers, the PI will transmit the project's software file where the data was analyzed.

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Bibliography

At the time of this report there are no publication that have resulted from the work performed under the award.